NOAA WAVEWATCH III

NCEP's operational ocean wave model

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Outline

What is a wave model ...
- (excerpts from the web page primer)

NCEP ocean wave guidance
- past
- present
- future

Strong and weak points of new models

Products
- what is available
- how to get it

Wind waves 1

Wind waves are the waves at sea that are generated by local or distant winds. Waves generated locally are usually referred to as wind sea. Waves generated at distant locations in the past are referred to as swell.

Wind waves range in wave height from negligible to 30m (100ft) and more, and in length (distance between consecutive waves) from centimeters to 1 km.

Corresponding wave periods (i.e., the time it takes for two consecutive waves to pass a given location) range from less than 1 second to about 25s.

http://polar.ncep.noaa.gov/waves/pres/primer

Wind waves 2

Although wind wave conditions generally change slowly, no two consecutive waves are identical. Furthermore, individual waves are so small that it would be practically impossible to predict every individual wave. Instead the wave field is described with average measures for wave heights.

The commonly used wave height to describe the wave field is the significant wave height H_s, which is usually defined as the average wave height of the highest 33% of all individual waves. Because smaller waves are generally not seen against the background of the larger ones, this corresponds closely to the visually observed mean wave height.

primer

Wind waves 3

Generally, it is assumed that individual wave heights can be described using a Rayleigh distribution. This implies that for a significant wave height H_s = 10m (33ft), one can expect :

1 in 10 waves to be larger than 10.7m (36ft).
1 in 100 waves to be larger than 15.1m (51ft).
1 in 1000 waves to be larger than 18.6m (62ft).

This implies that the largest individual wave that one might encounter in a storm is roughly twice as high as the significant wave height !

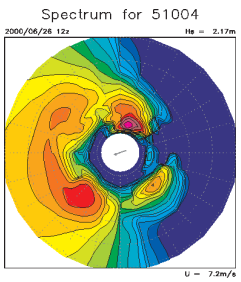
In rapidly changing conditions the disparity between the significant wave height and the largest individual waves might even be larger.

primer

Wave spectra 1

In advanced wave observations and inside wave models, the wave field is not described with a single wave height, but with a so-called wave spectrum, which describes the distribution of wave energy over wave directions and frequencies at a fixed location.

A graphical representation of such a spectrum as can be found on the web page is shown here (buoy location 51004, SE of Hawaii).

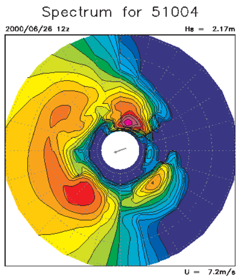


primer

Wave spectra
2

Dark blue indicates absence of wave energy, light purple the local maximum. Each new contour level corresponds to a factor of two increase of wave energy.

The direction relative to the center of the plot indicates the direction in which the waves travel. The frequency increases from about 0.04Hz (25s wave period) at the center of the plot to 0.25Hz (4s wave period) at the outside of the plot.



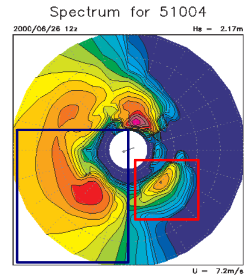
primer

Tolman/Alves   Western Region Marine Forecasters Training Workshop (5/03)

Wave spectra
3

The energy in the red box thus represents an individual wave field traveling in SE direction with a peak period of about 10s Because wave energy is concentrated in frequency and direction this corresponds to a fairly regular, well organized wave field.

The energy in the blue box travels in SW direction at lower periods, and is more chaotic as energy is distributed over a wider range in directions and frequencies.



primer

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Wave spectra
4

The spectral plots from the wave model mostly give qualitative information. The corresponding quantitative information can be found in the bulletins.

A piece of such a bulletin is presented below. The first column gives date and hour, the second the overall wave height and number of identified individual wave fields. The next six columns (only two shown here) identify wave fields by height, period and direction.

```
Location : 51004      (17.40N 152.50W)
 Model    : NWW3 global 1x1.25 degr.
 Cycle    : 20000626 t00z
+-------+-----------+-----------------+-------
| day & |  Hst  n x |     Hs   Tp dir |    H
|  hour |  (m)  - - |    (m)  (s) (d) |   (m)
+-------+-----------+-----------------+-------
| 25 12 |  1.9  7   |    1.0 17.5  19 |   1.0  7.0 292 |
| 25 13 |  1.9  7   |    1.0 17.6  19 |   1.0  7.0 292 |
| 25 14 |  1.9  6   |    1.1 17.6  19 |   0.9  7.1 292 |
```

AWIPS : feet, dir. from

primer

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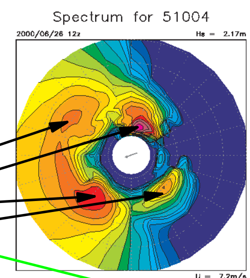
Wave spectra
5

The info in the spectral plots and the bulletins can be combined as follows (*Hs* is significant wave height, *Tp* is peak or dominant period)

Hs = 0.7m, *Tp* = 6.6s
Hs = 1.4m, *Tp* = 15.9s
Hs = 1.4m, *Tp* = 7.0s
Hs = 0.3m, *Tp* = 9.9s




```
| 26 12 |  2.2  4 | 1.4 15.9  16 | 0.7  6.6 306 | 1.4  7.0 239 | 0.3  9.9 136 |
```

primer

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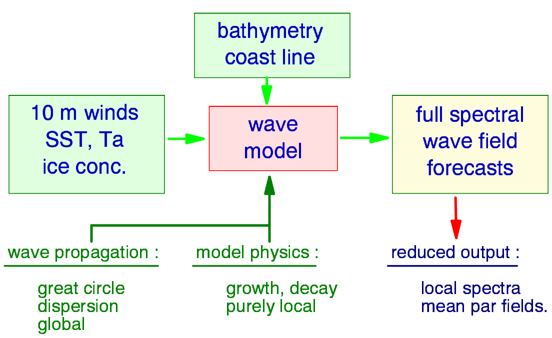
Numerical wave models



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NCEP Guidance (past)

Computer-aided wave forecasting started at the NWS in 1956. Since then, a patchwork of models has been developed. Up to March 9, 2000, the operational wave forecast suite of NCEP consisted of :

- Global WAM implementation at 2.5 x 2.5º.
- Regional east coast WAM implementation at 0.25 x 0.25º nested in a 1x1º basin model.
- Regional Gulf of Alaska model at 30 nm resolution (second generation model).

No longer availble in any form

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NCEP Guidance (now) 1

1993-now, development of new wave model WAVEWATCH III (based on WAM) :

- New governing equations :
  - Model ready for coupling to current models (Gulf Stream).
- New physics parameterizations :
  - Chalikov and Belevich input.
  - Tolman and Chalikov dissipation.
- New numerics :
  - Third order propagation.
  - Dynamically adjusted time steps.
- MPI version.

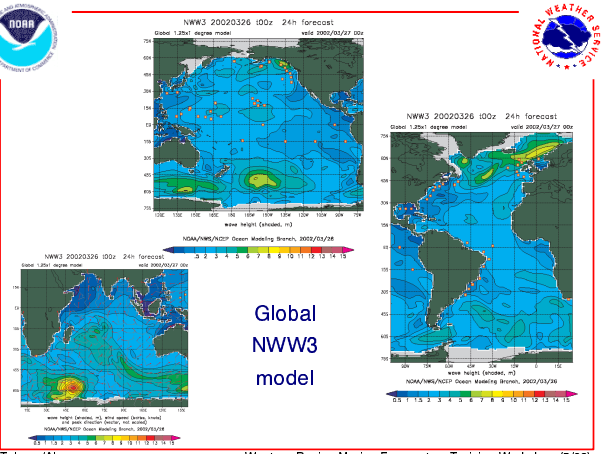
http://polar.ncep.noaa.gov/waves[/wavewatch]

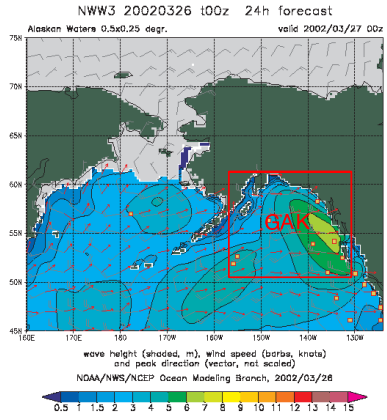
NCEP Guidance (now) 2

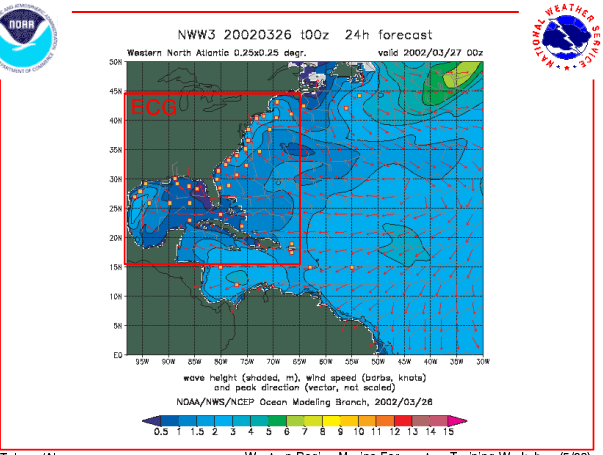
NOAA WAVEWATCH III system replaced all previous operational wave models at NCEP with:

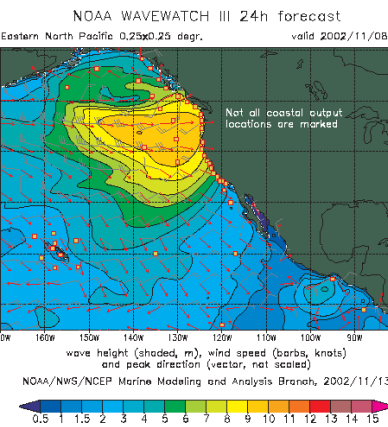
- Global 1.25x1° NWW3 model (168h).
- Alaskan Waters model (AKW, 0.5x0.25°, 168h).
- Western North Atlantic model (WNA, 0.25x0.25°, 168h), with seasonal Hurricane version (72h).
- Eastern North Pacific model (ENP, 0.25x0.25°, 168h), with Hurricane version (72h).
- All models use 24 directions, 25 frequencies, GFS winds, 00z, 06z, 12z and 18z cycle runs, 6 hour hindcasts for continuity.

http://polar.ncep.noaa.gov/waves









NCEP Guidance (now)

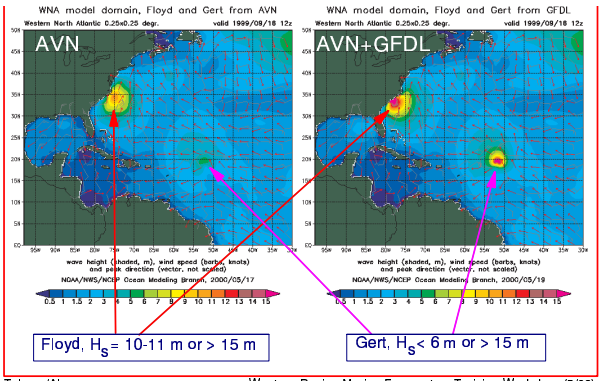
3

Why do we need a special Hurricane version (NAH, NPH) of regional models (WNA, ENP).

- Wave model can only be as good as the winds that drive it.
- Hurricane winds are not done particularly well by the GFS due to resolution problems and due to limitations of the model physics.
- Better results expected when higher resolution models are used such as the GFDL model.
- Need for blended GFS/GFDL winds.

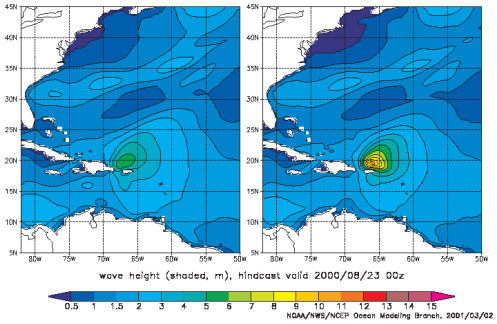
http://polar.ncep.noaa.gov/waves

Hurricanes Floyd and Gert (Chao & Tolman)



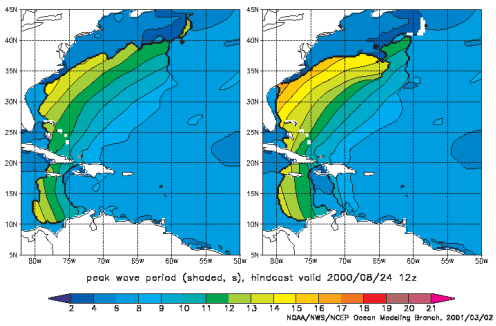
Debby significant wave height (m) 2000/08/22 00z

AVN winds AVN + GFDL winds



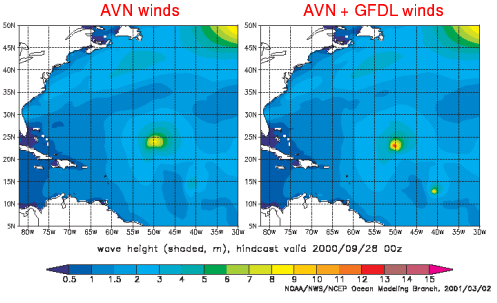
Debby peak wave period (s) 2000/08/23 12z (+ 36 h)

AVN winds AVN + GFDL winds



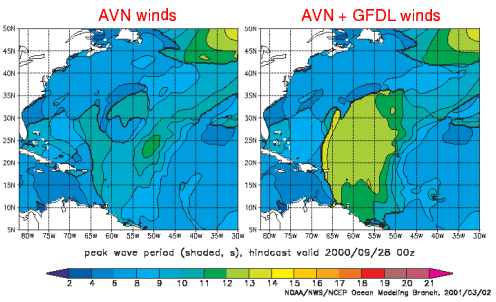
Isaac /Joyce significant wave height (m) 2000/09/28 00z

AVN winds AVN + GFDL winds



Isaac / Joyce peak wave period (s) 2000/09/28 00z

AVN winds AVN + GFDL winds

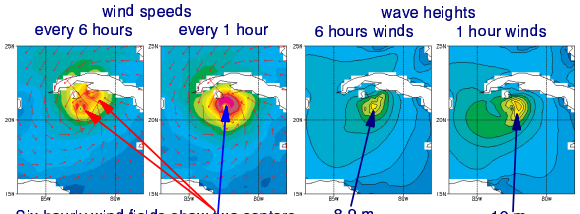


Guidance upgrades 1

- The following changes and of the model suite were made in the past year :
  - Upgrade of blending scheme for NAH winds and upgrade time resolution of NAH wind fields to 1 hour (start of 2002 Hurricane season).
  - Second release of WAVEWATCH III code ...
  - Four cycles, seven day forecast for all non-hurricane models.
  - Continuous upgrades to output points. New buoys and new requests added. West coast temporary output points removed from global. Old AFOS and DIFAX output disabled.

Guidance upgrades 2

Michelle at 11/04/2001 15z



Six hourly wind fields show two centers at off hour. These are in fact the centers at 12z and 18z, respectively. Unrealistic wind fields are caused by necessary interpolation, and do not occur with hourly winds.

8-9 m

10 m

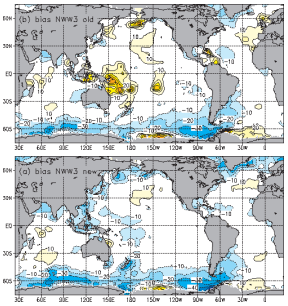
Wave heights from hourly winds are noisy and low. Wave heights from hourly fields are more consistent and higher.

Guidance upgrades 3

- The model itself is also subject to continuous development and tuning :
  - Fully allocatable FORTRAN 90 version.
  - Improved source term integration.
  - New propagation scheme, GSE, unresolved islands.

5 Yr
  - New physics.
  - Bug fixes, retuning.

Guidance upgrades 4



Bias for NWW3 model wave height against ERS-2 in cm without (top) and with (bottom) sub-grid islands

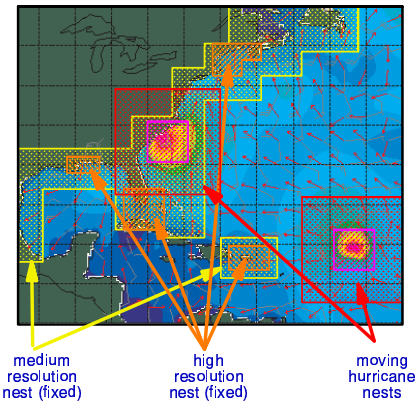
NCEP Guidance (future) 1

- There are no additional regional models planned. We also do not expect to upgrade the resolution of any of the models in the near future. Instead, we are working on the underlying WAVEWATCH model to :
  - Improve its physics.
  - Generate multiscale capability.
- We are working on data assimilation for the global NWW3 model.

NCEP Guidance (future) 2

The next step in expanding the functionality of WAVEWATCH III is to generate a multi-scale version:

- Two-way nesting of models with different scales that run simultaneously.
- Moving nests follow features of interest, particularly hurricanes. coupling with WRF
- Hurricane nests plus coastal nests remove the need for running separate large regional models.
- Selective application of highest resolution nests makes ensemble wave forecasting more feasible.
- Good potential for external funding from Navy.



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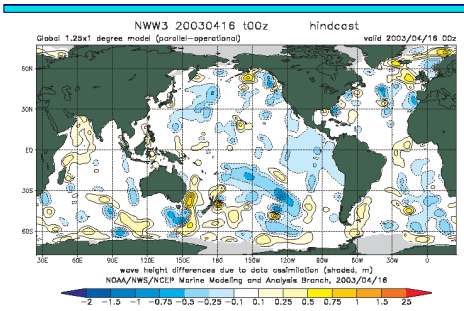
NCEP Guidance (future) 3



Effect of assimilation of buoy and ERS-2 altimeter data on global nowcast significant wave height.

Quality of Guidance

There is a large amount of validation data available at the web :

- Several statistics per month / season against buoys or satellite observations. Starting Feb 1997 for global model, Aug. 2000 for regionals.
- Results of a six-month comparison with old operational global model including a large number of time series plots.

http://polar.ncep.noaa.gov/waves/validation.html

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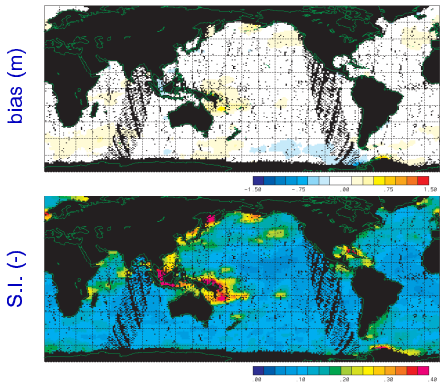
Model hindcast against altimeter (Hs)



Quality of Guidance

Strong points :

- Very similar to WAM in wind seas, better in swells.

Weak points :

- No shadowing of unresolved islands (Hawaii, Aleutian Islands). SOLVED
- Small scale systems not always sufficiently resolved (near-coast resolution). T254L64
- Initial growth (East Coast). General tendency of being a little slow in initial growth, compensating at end of storm

It is only a model, and can be only as good as its driving forces, i.e., the wind.

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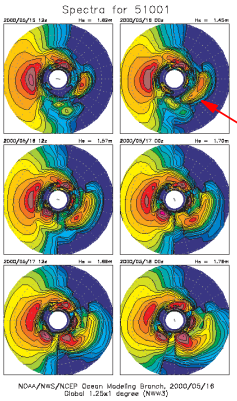
Products (what)

Mean wave parameters in GRIB format

- Overall significant wave height.
- Mean direction and period.
- Peak direction and period.
- Wind sea direction and period.
- NOT AVAILABLE : mean swell height and direction (see next slide).

Text bulletins with different wave systems for output locations.

There is rarely just one swell field. What is the meaning of "the" swell height and the mean swell period and direction?



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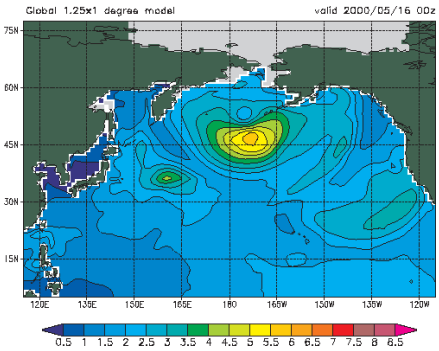
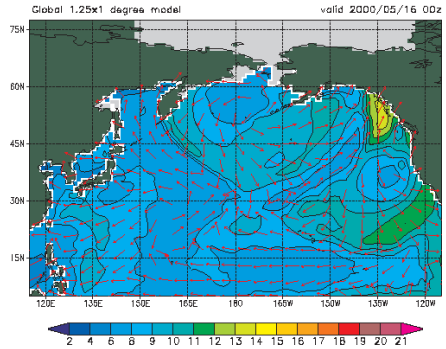
significant wave height (m)



mean wave period (s) and direction



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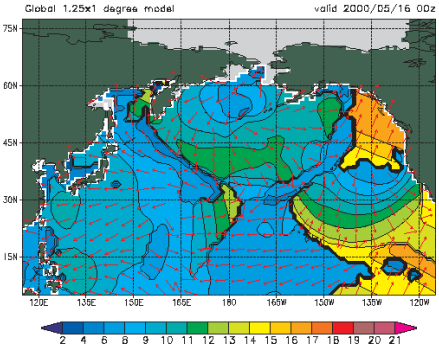
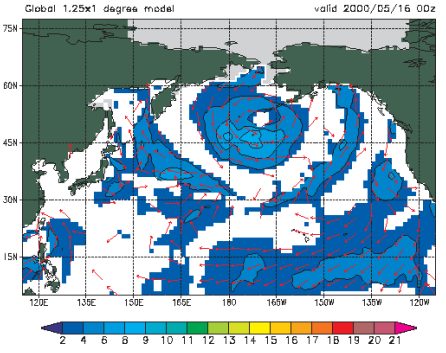
peak period (s) and direction



wind sea period (s) and direction



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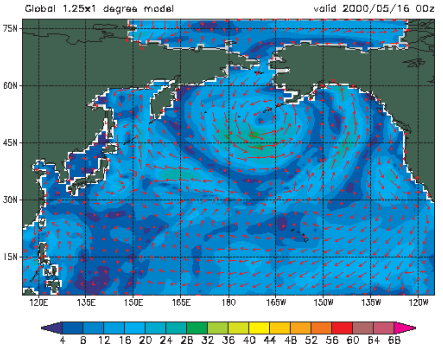
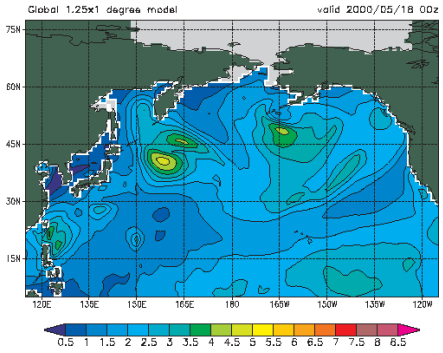
wind speed (kn) and direction



significant wave height (m)



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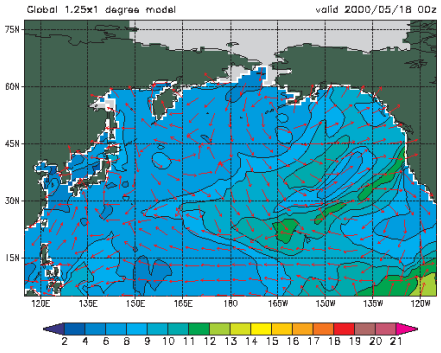
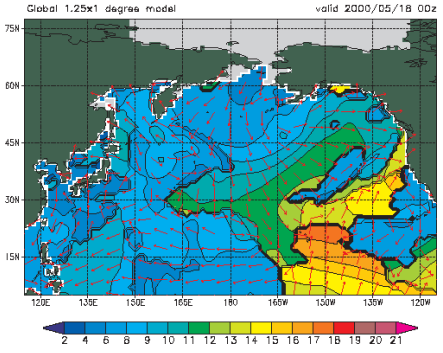
mean wave period (s) and direction



peak period (s) and direction



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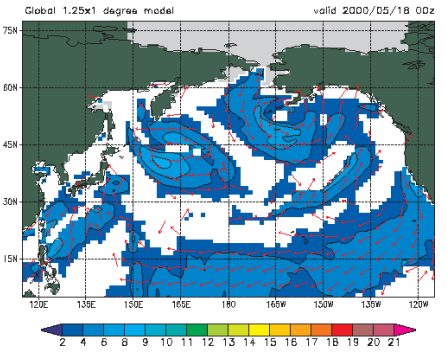
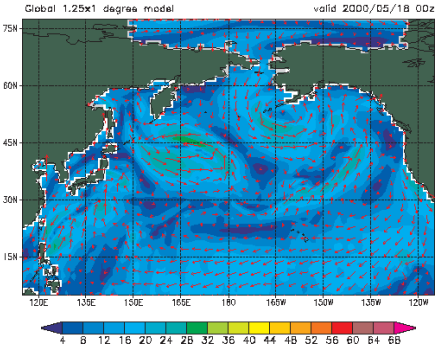
wind sea period (s) and direction



wind speed (kn) and direction



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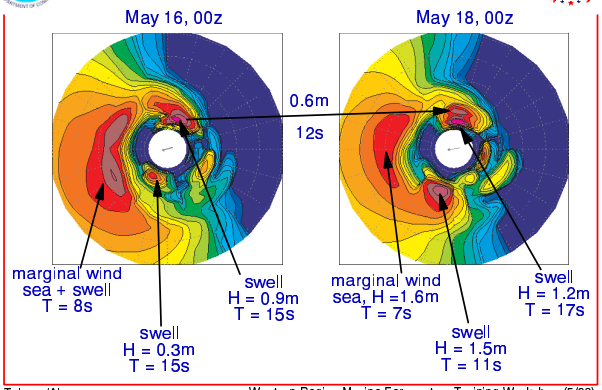
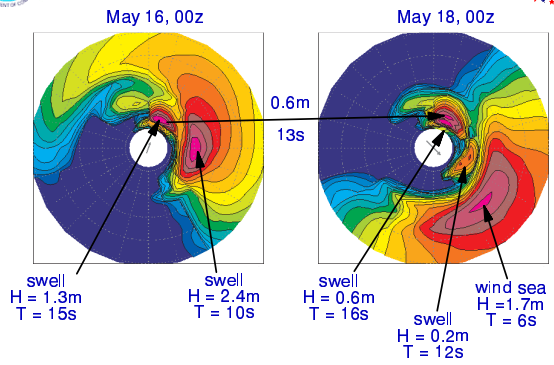
location 51004 (SE Hawaii)



Monterey (no buoy)



Products (where)

- Most model fields are now available in AWIPS. Errors in AWIPS graphics near coast. It takes some time to catch up with added cycles and extended forecast ranges.
- Text bulletins are on AWIPS in version modified for the use of WFOs.
- ALL model data availble on the web, usually within 1 hour of the model run.
- Historical hindcast data available on web.
- We will work with any WFO or region to get products out as needed.

http://polar.ncep.noaa.gov/waves
http://polar.ncep.noaa.gov/NEW.waves

Products (planned)

- Adding wind speed and direction to bulletin (web only). Providing third bulletin format that is readable by spreadsheets for easy display.
- Provide individual wave fields in space and time, in a way similar to what is done in bulletins for output points only now (with Jeff Hanson, JHU/APL).
- We are interested in additional parameters that are relevant for safety or other forecast issues, such as steepness. We would appreciate input from the field.

Finally ....

For questions, remarks, requests etc., contact us at

NCEP.EMC.waves@NOAA.gov

This E-mail will be distributed automatically among our entire wave staff, and therefore will give you the fastest response. To get us personally, try

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Henrique.Alves@NOAA.gov